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High specific strength, heat resistant Ni-Ti base alloy

Abstract:

Abstract of GB2287955

High specific strength, heat resistant Ni-Ti base alloy. The alloy has a nominal composition expressed NiaTibAlc (where a, b, and c are atom% fractions, a+b+c=100, a=from 45 to 60 and 0.5 </= c </= 18). Cr, Co, Mo, W, Hf, Nb, Ta, Re, V, B, C and Zr may be present singly or severally. Data supplied from the esp@cenet database - Worldwide

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U1S S1989 S2036

(56) Documents Cited
GB 1576533 A **GB 1413146 A** **GB 1350468 A**
GB 1350094 A **GB 0560957 A** **EP 0187452 A**

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(54) **High specific strength, heat resistant Ni-Ti base alloy**

(57) High specific strength, heat resistant Ni-Ti base alloy. The alloy has a nominal composition expressed $Ni_aTi_bAl_c$ (where a, b, and c are atom% fractions, a+b+c=100, a=from 45 to 60 and $0.5 \leq c \leq 18$).
Cr, Co, Mo, W, Hf, Nb, Ta, Re, V, B, C and Zr may be present singly or severally.

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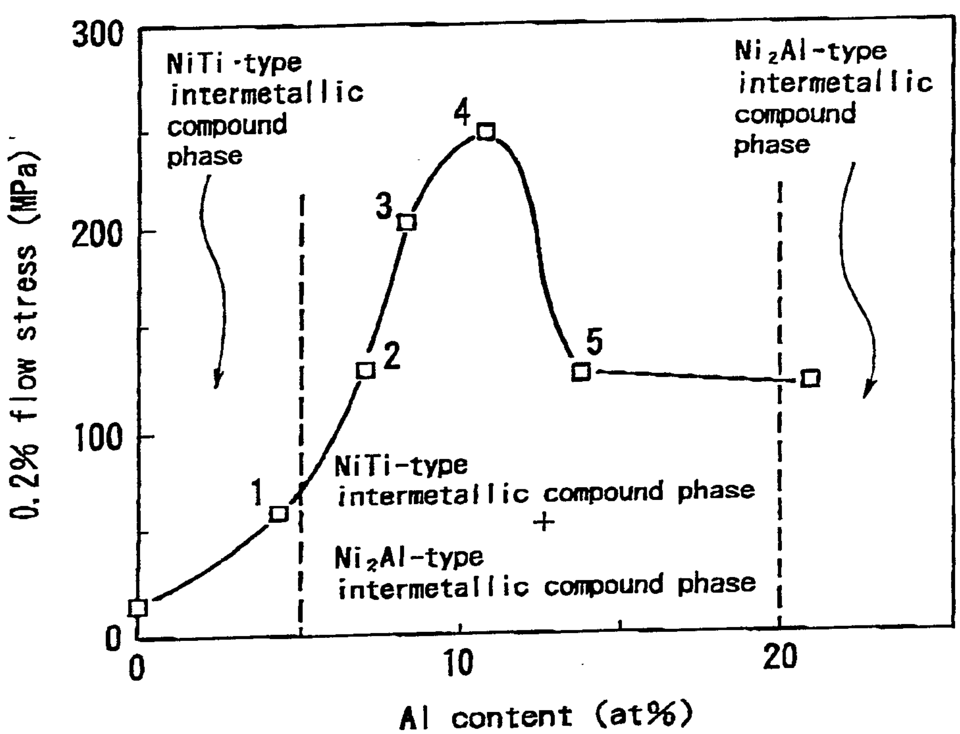
Figure



300
200
100
0
0
10
20
0.2% flow stress (MPa)
Al content (at%)
NiTi-type intermetallic compound phase
Ni2Al-type intermetallic compound phase
NiTi-type intermetallic compound phase + Ni2Al-type intermetallic compound phase
1
2
3
4
5

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HIGH SPECIFIC STRENGTH, HEAT RESISTANT NiTi-BASE ALLOYS

The present invention relates to a high specific strength, heat resistant alloy. More specifically, the present invention relates to a heat resistant NiTi-base alloy having high specific strength preferably applicable to structural members requiringhigh specific strength at a wide range of from relatively low temperatures to high.

The materials used in jet engine blades and disks as well as fuselage materials are subjected to extreme temperature gradients. For example, the outer disk material experiences temperatures exceeding 600℃ , while the inner temperature may be a relatively cool 200℃ . Therefore, the alloy used in these areas must be strong in a wide temperature range. The Ni base superalloys having high strength at high temperatures have been adopted as those materials up to now, but these superalloys have a serious defect in that their strength at relatively low temperatures is low. In particular, their specific weight is so high by 7.9-9.0 that tremendous centrifugal stress is loaded to inner areas of materials rotating at low temperatures. There is a limit to use the Ni base superalloys. At the same time, these alloys tend to make jet engines heavier. In terms of volume, turbine disks are particularly large, so it is necessary to reduce specific weight to achieve reduction in weight.

Recently, some proposal has been made in which a TiAl intermetallic compound having small specific weight of 3.9 is applied. This intermetallic compound, however, has low strength at low temperatures around room temperature (350-530MPa against 0.2% proof stress) and its specific strength is, at best, equal to that of the Ni base superalloy (90-136MPa/(g/cm^3). The above-mentioned problem has remained

unsolved.

The present invention provides a high specific strength, heat resistant alloy having a nominal composition expressed $Ni_aTi_bAl_c$ (where a, b, and c are atom% fractions, a+b+c=100, a=from 45 to 60 and $0.5 \leqq c \leqq 18$).

The present invention has been achieved based on the fact discovered by inventors that substitution of Al for a part of Ti in the NiTi intermetallic compound exclusively used for shape-memory alloys improves strength greatly both at high temperatures and at room temperature. Specific strength improved by the partial substitution of Al for Ti is equal to that of the conventional Ni base superalloy at high temperatures around 1000℃, and it is enhanced by two or three times at room temperature compared to that of the Ni base superalloy. Specific weight, on the other hand, goes down 20% compared with that of the superalloy. This fact tells us that the alloy is useful for achieving reduction in weight.

The amount of Ni, or an atom% fraction expressed "a" in the nominal composition, is within a range in which harmful phases to cause toughness to deteriorate are not precipitated at all. If "a" exceeds beyond 60 atom%, harmful phases such as a Ni_3Ti phase form easily. Under 45 atom% of "a", a Ti_2Ni harmful phase comes to form. Toughness of the alloy decreases in both cases.

Addition of Al improves strength as well as oxidation resistance of the alloy, but if the amount of Al expressed "c" in the nominal composition exceeds 18 atom%, the amount of a Ni_2AlTi type compound phase is so excessive that ductility deteriorates. The Al fraction is, therefore, limited to the range of $0.5 \leqq c \leqq 18$, preferably, $5 \leqq c \leqq 15$.

The Ni_2AlTi type compound precipitates in a sufficient amount under 5 atom% of "c", but the excessive amount beyond 15 atom% causes the amount of the Ni_2TiAl type compound phase to slightly exceed, this influencing strength of the alloy.

With regard to the Al fraction, another preferable range is $0.5 \leqq c \leqq 5$. The alloy substantially consists of a single phase of the NiTi type intermetallic compound within this range. This alloy is slightly inferior to the two-phase alloy above-mentioned in strength, but its ductility is sufficient for the practical use. The Al fraction of below 0.5 atom% leads to low strength.

Several performances of the alloys of the present invention may be further improved by the well-known manners for heat resistant materials. These manners are as follows:

1) Singular or plural elements selected from among Co, Cr, Mo, W, Nb, Ta, Hf, Re and V may be added which are usually adopted for strengthening heat resistant materials.

2) Singular or plural elements, in general, effective for improving oxidation resistance and high temperature corrosion resistance, for example, Cr, Hf and Re, may be added to do so.

3) Singular or plural elements selected from among C, B and Zr may be added which are famous for their effective function for improving grain boundary strength of polycrystalline materials.

4) Structure control may be conducted by the well-known manner such as a directional solidification method, a single crystal solidification method and a powder metallurgy.

5) Microstructure control may be conducted by heat

treatment such as solution heat treatment and subsequent annealing which are typically applied to the two-phase alloy. Thermo-mechanical treatment may be very effective to improve microstructure and mechanical properties.

At any rate, the alloy of the present invention may probably be fundamental to alloys with any additive as in the case of the conventional Ni base superalloy. The Ni base superalloy mainly consists of two fundamental phases of Ni/Ni_3Al and several additives are added.

Some embodiments of the present invention will now be described by way of example and with reference to accompanying drawing, in which:

Figure is a diagram illustrating the effect of substitution of Al in a NiTi system alloy on strength.

Examples 1 to 5

NiTi alloys and a series of alloys substituted by Al for Ti in the NiTi system were produced by melting. These compositions are shown in Table 1 together with compositions of the well-known Ni base superalloy. Specific weight of these alloys is also shown. The typical Ni base superalloys have specific weight of 7.9 to 8.2, but specific weight of the alloys of the present invention is 6.5 and goes down 20% compared with those of the conventional ones. This fact suggests it to us that weight of members such as turbine disks may be reduced by the alloy of the present invention. Since the frame composition of the present invention consists of three elements of Ni, Ti and Al, the alloy holds cost down to produce compared with the conventional superalloys including several expensive additive elements.

Table 1

Alloy composition (atom%)

Alloy	Ni	Co	Cr	Mo	Al	Ti	C	B	Zr
Waspalloy	balance	13.0	21.3	2.6	2.7	3.6	0.4	0.03	0.04
U500	balance	18.0	19.3	2.4	6.2	3.5	0.3	0.04	0.03
U700	balance	17.4	16.0	3.0	8.8	4.0	0.4	0.2	–
NiTi	49.8	–	–	–	–	50.2	–	–	–
Example 1	50.1	–	–	–	4.4	45.5	–	–	–
2	50.1	–	–	–	7.1	42.8	–	–	–
3	50.7	–	–	–	8.4	40.9	–	–	–
4	50.8	–	–	–	11.0	38.2	–	–	–
5	50.5	–	–	–	13.9	35.6	–	–	–

Specific weight

Alloy	Specific weight
Waspalloy	8.2
U500	7.9
U700	7.9
NiTi	6.5
Example 1	6.5
2	6.5
3	6.5
4	6.5
5	6.5

Subsequently, specimens having a column shape were prepared for a compression test and they, as cast materials, were subjected to strength test both at room temperature and at 1000°C . A hardness test was also carried out at room temperature. The results are shown in Table 2 together with published values of the Ni base superalloys for comparison.

Table 2

Results of strength test

Alloy	Hardness at room temp.	Strength at room temp.		Strength at 1000°C	
	(Vickers)	0.2% proof stress	Specific strength	0.2% proof stress	Specific strength
Waspalloy	–	795	97	78	9
U500	–	840	106	187	24
U700	–	965	122	269	34
NiTi	253	260	40	17	2
Example 1	408	1098	170	58	9
2	561	1645	255	139	22
3	642	2290	352	202	31
4	639	–	–	247	38
5	730	–	–	125	19

Unit 0.2 proof stress : MPa
Specific strength : MPa/(g/cm^3)

As is clear from Table 2, partial substitution of Al for Ti in the NiTi alloy greatly enhances strength properties including hardness. For specific strength, the alloy of the present invention is equal to the conventional Ni base superalloy at 1000℃ and far more excellent at room temperature. Rotary members such as turbine disks should require high specific strength at relatively low temperature range of from room temperature to 200℃ as well as high temperature range. Since the alloy of the present invention has much higher strength at relatively low temperatures than the conventional Ni base superalloy does, a turbine made of the alloy may possibly bear centrifugal force. It is possible to rotate a turbine with a high speed and obtain high output performances. In addition, weight of the turbine is reduced because of small specific weight of the alloy. This alloy has significant effects on turbines for airplanes such as jet engines.

Expensive elements such as Co, Cr, Mo, W, Nb, Ta, Hf, Re and V are optional additives for the alloy of the present invention, while they are essential for the conventional Ni base superalloy. This fact contributes to holding cost down.

Figure attached herewith shows the effect of substitution of Al in the NiTi system alloy on the strength of the alloy. It is clearly confirmed that replacement of Al for Ti greatly improves strength of the NiTi alloys at 1000℃.

As described in detail in the above, specific strength of the heat resistant NiTi-base alloy is enhanced by addition of Al.

It is needless to mention that the present invention is

not limited to these embodiments.

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Claims

1. A high specific strength, heat resistant alloy having a nominal composition expressed $Ni_aTi_bAl_c$ (where a, b, and c are atom% fractions, a+b+c=100, a=from 45 to 60 and $0.5 \leq c \leq 18$).

2. A high specific strength, heat resistant alloy as claimed in claim 1, wherein an Al fraction is from 5 to 15 atom% and said alloy is a two-phase alloy substantially consisting of a NiTi type intermetallic compound phase and a Ni_2AlTi compound phase.

3. A high specific strength, heat resistant alloy as claimed in claim 1, wherein an Al fraction is from 0.5 to 5 atom% and said alloy substantially consists of a single phase of a NiTi intermetallic compound.

4. A high specific strength, heat resistant alloy as claimed in claim 1 substantially as hereinbefore described.

5. A high specific strength, heat resistant alloy substantially as hereinbefore described with reference to the examples.

6. A high specific strength, heat resistant alloy substantially as hereinbefore described with reference to the accompanying drawing.

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Patents Act 1977
Examiner's report to the Comptroller under Section 17
(ꞓ Search report)

Application number
GB 9504882.3

Relevant Technical Fields

(i) UK Cl (Ed.N) C7A

(ii) Int Cl (Ed.)

Databases (see below)
(i) UK Patent Office collections of GB, EP, WO and US patent specifications.

(ii)

Search Examiner
R B LUCK

Date of completion of Search
5 APRIL 1995

Documents considered relevant following a search in respect of Claims :-
1-6

Categories of documents

X: Document indicating lack of novelty or of inventive step.

Y: Document indicating lack of inventive step if combined with one or more other documents of the same category.

A: Document indicating technological background and/or state of the art.

P: Document published on or after the declared priority date but before the filing date of the present application.

E: Patent document published on or after, but with priority date earlier than, the filing date of the present application.

&: Member of the same patent family; corresponding document.

Category	Identity of document and relevant passages		Relevant to claim(s)
X	GB 1576533	(BROWN BOVERI & CO) see page 3 lines 1-5	1 at least
X	GB 1413146	(RAYCHEM CORP) see note 2 in Table 1	1 at least
X	GB 1350468	(FURAKAWA ELECTRIC CO LTD) see Al-containing alloys in Tables 2, 3, and 4)	1 at least
X	GB 1350094	(FURAKAWA ELECTRIC CO LTD) see Al-containing alloys in Tables 2 and 3	1 at least
X	GB 560957	(MOND NICKEL CO) see page 2 lines 27-33	1 at least
X	EP 0187452	(RAYCHEM CORP) see Example 6	1 at least

Databases: The UK Patent Office database comprises classified collections of GB, EP, WO and US patent specifications as outlined periodically in the Official Journal (Patents). The on-line databases considered for search are also listed periodically in the Official Journal (Patents).